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(54) Bipolar plate for fuel cells comprises single integral metal sheet having raised regions forming contact surfaces and gas flow paths

(57) A bipolar plate for the separation and contact of the anode (1) and cathode (2) of adjacent fuel cells (9) arranged in a fuel cell stack (8) is formed by a single integral sheet metal body (400) which has a plurality of first raised regions (410) facing the anode and forming contact surfaces for the anode, and separated from each other by intermediate spaces, and a plurality of second raised regions (420) facing the cathode and forming contact surfaces for the cathode, and separated from each other by intermediate spaces, the intermediate spaces between the first raised regions (410) forming flow paths for the fuel gas (B) flowing on the anode side of the bipolar plate and the intermediate spaces between the second raised regions (420) forming flow paths for the cathode gas (K) flowing on the cathode side of the bipolar plate.

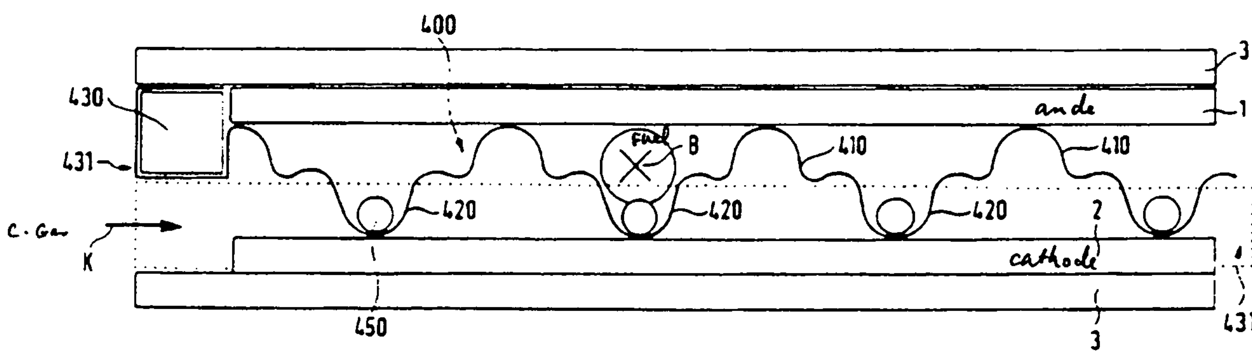

FIG. 4

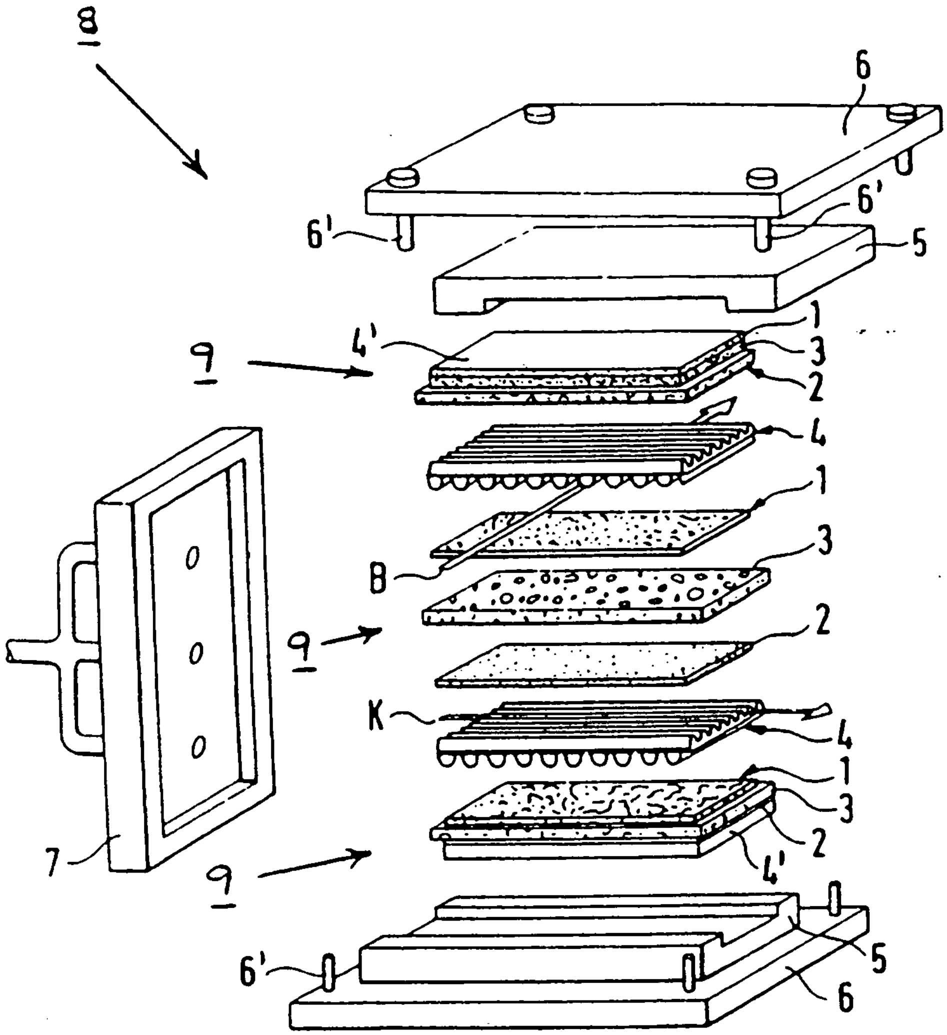

FIG.1

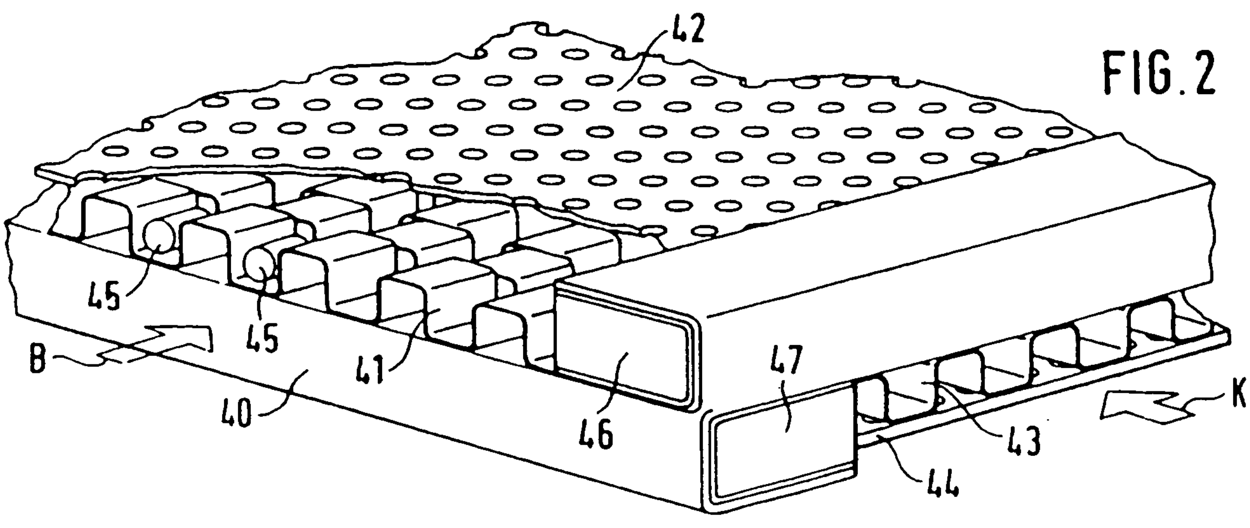

FIG.2

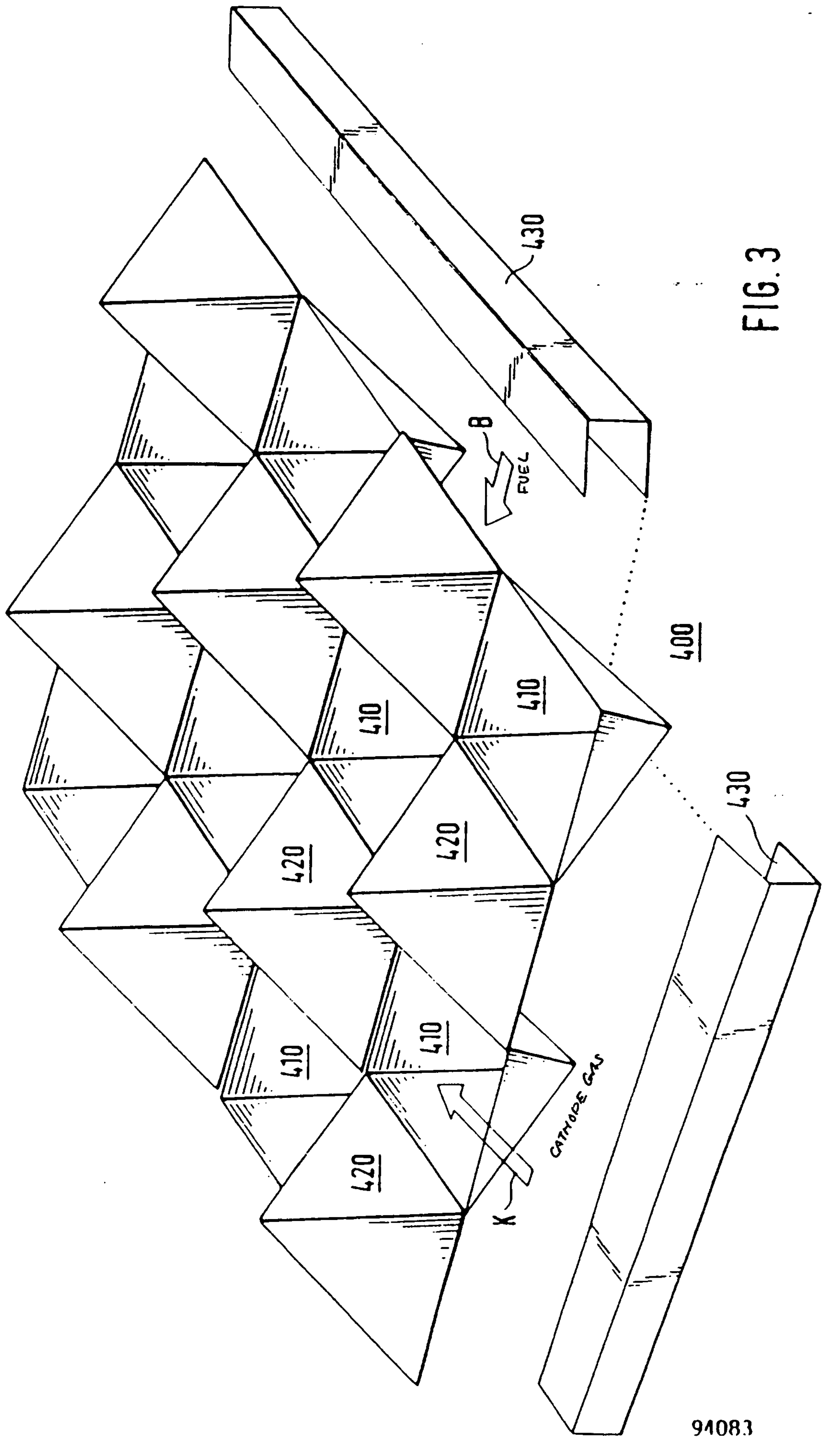

FIG.3

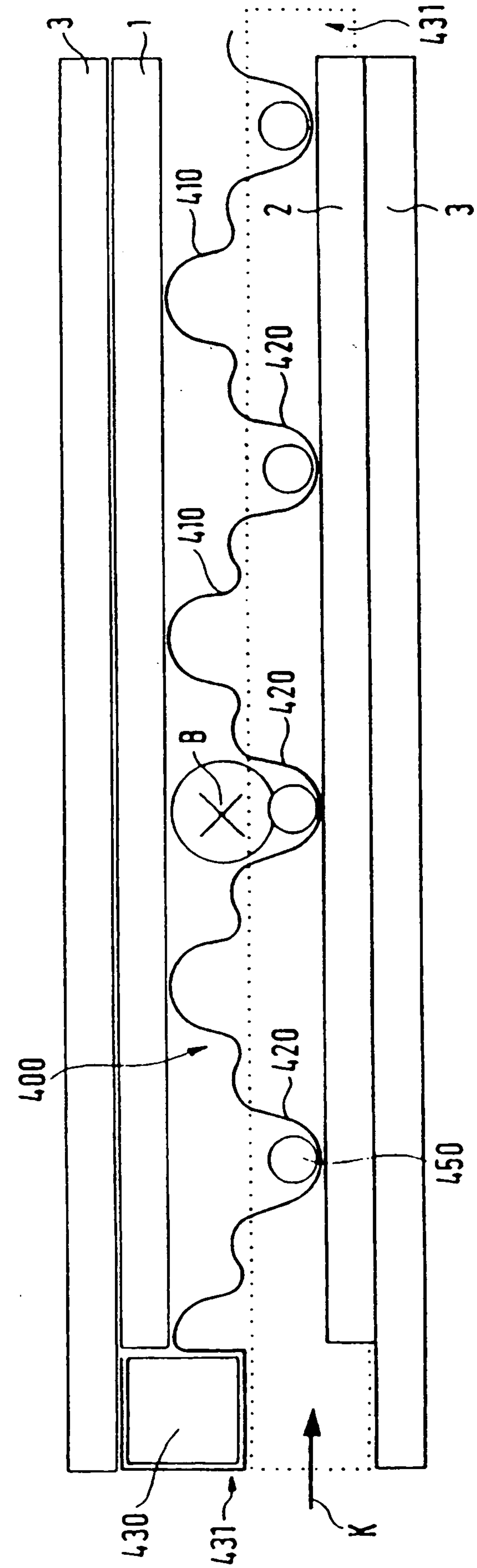

FIG. 4

A BIPOLAR PLATE FOR FUEL CELLS

This invention relates to a bipolar plate for the separation and contact of the anode and cathode of adjacent fuel cells arranged in a fuel cell stack.

Modern fuel cell arrangements, particularly fuel cell arrangements based on molten carbonate technology, comprise a plurality of individual fuel cells arranged one above another in a fuel cell stack, so that they can be connected in series electrically and can be connected in parallel as regards their gas flow configuration. Within a fuel cell stack such as this, the individual cells are separated from each other by what is termed a bipolar plate. The function of the bipolar plate is

- to separate the gas space at the anode of a fuel cell from the gas space at the cathode of the adjacent fuel cell,
- to provide a flow cross-section within which the gas is supplied to the anode or cathode and is discharged again from the latter,
- to provide space for accommodating a catalyst for internal reforming, and
- to form electrical contacts between the anode and cathode of adjacent fuel cells.

Known, conventional bipolar plates are built up from a number of individual elements, the object of which is to perform a plurality of the above-mentioned functions, individually or in cooperation. Thus a conventional bipolar plate consists of

- a metal separator plate, which is manufactured from stainless steel and is preferably nickel-plated on the anode side, and which effects separation of the gas spaces,
- a perforated, cathode current collector made of nickel-plated stainless steel in the form of a corrugated plate, which apart from its current collection function forms the anode gas space and provides space for receiving a catalyst material for internal reforming,
- a perforated, anode current collector made of stainless steel in the form of a corrugated plate, which forms the cathode gas space,

- a perforated plate of nickel on the anode side, which ensures uniform mechanical support of the anode,
- a perforated plate of stainless steel on the cathode side for supporting the cathode, and
- edge closure strips of stainless steel, which seal the edge regions and contribute to the stabilisation of the fuel cell stack.

The construction of a conventional bipolar plate such as this from a plurality of the aforementioned parts results in various disadvantages. Due to the large number of parts, the costs of material, production and assembly are high; high electrical contact resistances occur between the individual parts, and can assume considerable values, particularly on the cathode side in the reducing atmosphere thereof; nickel-plating the anode current collector results in considerable expense, since this component cannot be nickel-plated until stamping has been effected, in order to ensure that all the cut edges are nickel-plated. It is not possible to construct the anode current collector of nickel sheet, on account of the mechanical properties of the latter.

It would be desirable to be able to create a bipolar plate for fuel cells which is of simple construction.

According to the present invention, there is provided a bipolar plate of the presupposed type that is formed by a single integral sheet metal body which has a plurality of first raised regions facing the anode and forming contact surfaces for the anode, and separated from each other by intermediate spaces, and a plurality of second raised regions facing the cathode and forming contact surfaces for the cathode, and separated from each other by intermediate spaces, wherein the intermediate spaces between the first raised regions form flow paths for the fuel gas flowing on the anode side of the bipolar plate and the intermediate spaces between the second raised regions form flow paths for the cathode gas flowing on the cathode side of the bipolar plate.

A significant advantage of the bipolar plate according to the invention is its construction from a single piece, due to which electrical points of contact within individual elements

of the bipolar plate are eliminated. Electrical contact resistances are thereby eliminated, and the internal ohmic resistance of the fuel cell stack is thus eliminated. The generation of heat is thereby reduced and an improvement in efficiency is obtained.

Another advantage is that the bipolar plate according to the invention, in contrast to conventional current collectors, has no lateral sides of punched holes, so that it does not have to be expensively nickel-plated after it has been manufactured, but the bipolar plate can be manufactured instead from sheet metal which has previously been nickel-plated on one side, e.g. from roll-bonded sheet metal. This leads to considerable cost savings.

A further advantage is that the one-piece construction of the bipolar plate according to the invention results in savings in weight and in the cost of assembly compared with the conventional construction comprising five individual metal sheets.

In the description given below, the conventional construction of a bipolar plate is first described, followed by embodiments of the bipolar plate according to the invention, with reference to the accompanying drawings in each case. The drawings are as follows:

Figure 1 is an exploded perspective view of a fuel cell stack with conventional bipolar plates;

Figure 2 is an enlarged perspective view, shown partially sectioned, of a conventional bipolar plate;

Figure 3 is a schematic, perspective view of a bipolar plate according to a first embodiment of the invention; and

Figure 4 is a schematic partial view of a second embodiment of the bipolar plate according to the invention, in its installed state.

In the exploded perspective view of a fuel cell stack comprising molten carbonate fuel cells shown in Figure 1, the fuel cell stack is denoted overall by reference numeral 8.

For the sake of enhanced clarity, only three fuel cells 9 are shown. Each of the fuel cells 9 contains a highly porous anode 1 made of a nickel alloy, a highly porous cathode 2 made of nickel oxide doped with lithium, and a matrix 3, which is embedded between the anode 1 and cathode 2, and in which a molten electrolyte formed by an alkali carbonate melt is fixed. The bipolar plate according to the invention is not of course restricted to the use of a molten alkali carbonate fuel cell such as this. In the illustration of Figure 1, the anode 1, cathode 2 and matrix 3 of the top and bottom fuel cells are shown in their assembled state, whilst these parts are shown separated from each other, as an exploded view, in the fuel cell 3 which is illustrated in the middle.

A bipolar plate 4 is disposed between each two adjacent successive fuel cells 9 in the stack. These bipolar plates 4 separate the gas space at the anode 1 of a fuel cell 9 from the gas space at the cathode 2 of the adjacent fuel cell and simultaneously make the respective flow cross-section available within which the fuel gas B is passed over the anode and the cathode gas K is passed over the cathode. In the illustration of Figure 1, the fuel gas B is passed from front to back through the anode gas space on the underside of the bipolar plate 4, whilst the cathode gas K is passed from left to right through the cathode gas space on the top side of the bipolar plate 4. Distribution and combination of the gas flows is effected by gas distributors 7 disposed on all four sides of the fuel cell stack 8, only one of which gas distributors is illustrated for the sake of clarity.

Partial bipolar plates 4' are disposed in each case on the top side of the uppermost fuel cell 9 and on the underside of the lowermost fuel cell 9, each of which partial bipolar plates only contains the part required for forming the respective gas space at the anode 1 of the uppermost fuel cell or at the cathode 2 of the lowermost fuel cell.

The uppermost and lowermost fuel cells 9 are electrically insulated from end plates 6 by their respective insulating plates 5. The fuel cell stack 8 is held together by four screw bolts 6', which extend at the corners but which are only partially illustrated in the Figure.

Figure 2 is a perspective view of part of a conventional bipolar plate. This bipolar plate is constructed from five individual plate elements which are assembled to form the bipolar plate. These plate elements comprise a separator plate 40 which is manufactured from stainless steel and is nickel-plated on the anode side, and which effects separation of the gas spaces, and a perforated anode current collector 41 in the form of a corrugated metal sheet, which is likewise made of nickel-plated stainless steel, the function of which is to collect the current at the anode and to form the anode gas space, and which in addition provides space for receiving a catalyst material 45 for an internal reforming reaction. A perforated anode plate 42 made of nickel, which serves to provide uniform mechanical support of the anode, is disposed above the anode current collector 41. This perforated anode plate 42 is directly in contact with the anode. Under the separator plate 40 there is a cathode current collector 43 in the form of a corrugated sheet made of stainless steel, which forms the cathode gas space. In contrast to the anode current collector 41, the cathode current collector 43 does not have to be nickel-plated. Under the cathode current collector 43 there is a cathode perforated plate 44 made of stainless steel, which serves to support the cathode and is in direct contact with the latter. The conventional bipolar plate is formed by these five aforementioned individual elements. In addition, the bipolar plate also has edge closure strips 46 and 47, which serve for the lateral delimitation of the gas spaces at the anodes and cathodes, respectively, and for the mechanical stabilisation of the entire fuel cell stack. These edge closure strips 46, 47 should not be considered to be constituents of the bipolar plate in the strictest sense thereof, however.

The embodiment of the bipolar plate which is shown schematically in perspective in Figure 3 is formed by a single integral sheet metal body 400. The latter has a plurality of first raised regions 410 on its side facing the anode (the anode is not illustrated, but is to be imagined on the underside of the bipolar plate). A plurality of second raised regions 420 is correspondingly formed on the side facing the cathode (the cathode is likewise not illustrated, but is to be imagined on the top side of the bipolar plate). Whereas only eight each of the first and second raised regions 410 and 420, respectively, are shown in the Figure for the sake of clarity, there are very many more of them in practice, of course. The tips of the raised regions 410 and 420 each form contact

regions or surfaces for the contact of the respective electrode, namely the anode which is to be imagined below the bipolar plate and the cathode which is to be imagined above the bipolar plate. Edge closure strips 430, which are merely illustrated schematically in Figure 3, are provided on each of the longitudinal sides of the bipolar plate.

The intermediate spaces between the first raised regions 410 form flow paths for the fuel gas B flowing on the anode side of the bipolar plate, whereas the intermediate spaces between the second raised regions 420 form flow paths for the cathode gas K flowing on the cathode side of the bipolar plate.

The first and second raised regions 410, 420 are preferably each disposed at regular intervals from each other. So as to be able to adapt to the flow conditions and to other parameters which are typical of the fuel cell, the intervals may also be selected so that they are not regular.

In the second embodiment of the bipolar plate according to the invention shown in Figure 4, the first and second raised regions 410 and 420 are of dome-shaped construction. Compared with the pyramidal shape of the raised regions in the embodiment shown in Figure 3, this latter construction results in an enlargement of the contact area for the anode and cathode, and also results in the bipolar plate having the property of resilience, which ensures a more uniform compressive effect on the arranged fuel cells and ensures that variations in stress are equalised. For this purpose, the dome-shaped first and second raised regions 410 and 420 may be of more or less spherical construction. A catalyst material in the form of pellets 450, which serves for the internal reforming of the fuel gas B passed over the anode, is disposed between the raised regions 410 on the anode side. These catalyst pellets 450 are thus introduced on the back of the second raised regions 420 facing the cathode.

The sheet metal body 400 of the bipolar plate is preferably manufactured by stamping, pressing or deep-drawing the first and second raised regions 410, 420 from a piece of flat stainless steel sheet which is nickel-plated on the anode side.

In the embodiment illustrated in Figure 3, the first and second raised regions 410, 420 are arranged alternately in the manner of a chequerboard pattern, wherein the lattice constants of the chequerboard pattern can be adapted to the flow conditions and to other parameters specific to the fuel cell. In a first direction, which is the principal direction of flow of the anode gas B, the first raised regions 410 are arranged alternately in succession corresponding to the rows of the chequerboard-like arrangement, whereas in a second direction which is perpendicular to the first direction and which is the principal direction of flow of the cathode gas K, the second raised regions 420 follow each other alternately corresponding to the columns of the chequerboard-like arrangement.

As a variant of this embodiment, the chequerboard-like arrangement may be selected so that the respective directions of flow of the fuel gas B and the cathode gas K coincide with the diagonals of the chequerboard patterns, which results in a decrease in the resistance to flow.

As distinct from the pyramidal or dome-shaped construction of the raised regions 410, 420 in the two embodiments described above, other shapes are also possible. Thus the first and second raised regions 410, 420 may also be of barrel-shaped construction. In this respect it is possible, for example, for the long axes of the barrel-shaped first regions 410 to be disposed perpendicular to the long axes of the barrel-shaped second regions 420, wherein the long axes of the first raised regions 410 facing the anode are parallel to the principal direction of flow of the fuel gas B and the long axes of the second raised regions 420 facing the cathode are parallel to the principal direction of flow of the cathode gas K. This firstly results in an increase in the area of contact between the respective raised regions 410, 420 and the electrodes seated against them, i.e. the anode and cathode, respectively, of the adjacent fuel cell in each case, and secondly the resistance to flow is not significantly increased.

It is also possible, for the raised regions 410 and 420 to be fashioned differently, e.g. for one raised region to be pyramidal or dome-shaped and for the other raised region to be barrel-shaped.

It is also possible to flatten the raised regions, which are of pyramidal, dome-shaped or barrel-shaped construction, or which are of other forms of construction, in a direction parallel to the principal plane of the bipolar plate, and thereby to increase the areas of contact with the electrodes. This flattening may also be selected differently for raised regions of one type and another, so as to adapt the bipolar plate to different mechanical and strength properties of the anode and cathode, for example.

CLAIMS

1. A bipolar plate for the separation and contact of the anode and cathode of adjacent fuel cells arranged in a fuel cell stack, characterised in that the bipolar plate is formed by a single integral sheet metal body which has a plurality of first raised regions facing the anode and forming contact surfaces for the anode, and separated from each other by intermediate spaces, and a plurality of second raised regions facing the cathode and forming contact surfaces for the cathode, and separated from each other by intermediate spaces, wherein the intermediate spaces between the first raised regions form flow paths for the fuel gas flowing on the anode side of the bipolar plate and the intermediate spaces between the second raised regions form flow paths for the cathode gas flowing on the cathode side of the bipolar plate.

2. A bipolar plate according to claim 1, characterised in that the first and second raised regions are disposed at regular intervals from each other in each case.

3. A bipolar plate according to claim 2, characterised in that the first and second raised regions are arranged alternately in the manner of a chequerboard pattern.

4. A bipolar plate according to claim 3, characterised in that in a first direction, which is the principal direction of flow of the fuel gas, and in a second direction perpendicular to the first direction, which second direction is the principal direction of flow of the cathode gas, first and second raised regions are arranged alternately in succession corresponding to the rows and columns of the chequerboard-like arrangement.

5. A bipolar plate according to claim 3, characterised in that in a first direction, which is the principal direction of flow of the fuel gas and in a second direction perpendicular to the first direction, which second direction is the principal direction of flow of the cathode gas, only the first or only the second raised regions are arranged in

succession in each case, corresponding to the diagonals of the chequerboard-like arrangement.

6. A bipolar plate according to any one of claims 1 to 5, characterised in that the first and/or second raised regions are of pyramidal construction.

7. A bipolar plate according to any one of claims 1 to 6, characterised in that the first and/or second raised regions are of dome-shaped construction.

8. A bipolar plate according to any one of claims 1 to 7, characterised in that the first and/or second raised regions are of barrel-shaped construction.

9. A bipolar plate according to claim 8, characterised in that the long axes of the first regions of barrel-shaped construction are perpendicular to the long axes of the second regions of barrel-shaped construction, wherein the long axes of the first raised regions facing the anode are parallel to the principal direction of flow of the fuel gas and the long axes of the second raised regions facing the cathode are parallel to the principal direction of flow of the cathode gas.

10. A bipolar plate according to any one of claims 6 to 9, characterised in that the first and/or second raised regions of pyramidal, dome-shaped or barrel-shaped construction have flattened contact surfaces for the anode or the cathode, respectively.

11. A bipolar plate according to any one of claims 6 to 10, characterised in that the first and second raised regions are of identical construction.

12. A bipolar plate according to any one of claims 6 to 10, characterised in that the first and second raised regions are of different construction.

13. A bipolar plate according to any one of claims 1 to 12, characterised in that the sheet metal body of the bipolar plate is produced from a piece of flat sheet metal by stamping, pressing or deep-drawing the first and second raised regions.

14. A bipolar plate according to any one of claims 1 to 13, characterised in that the sheet metal body is produced from a stainless steel sheet.

15. A bipolar plate according to claim 14, characterised in that the stainless steel sheet is nickel-plated on the anode side.

16. A bipolar plate according to any one of the preceding claims, characterised in that catalyst pellets are disposed in the intermediate spaces between the first raised regions on the anode side.

17. A bipolar plate according to any one of claims 1 to 15, characterised in that the bipolar plate is provided with a catalyst coating on the anode side.

18. A bipolar plate substantially as described with reference to and as illustrated by Figs. 3 and 4 of the accompanying drawings.

Patents Act 1977 12
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9520957.3

Relevant Technical Fields

(i) UK Cl (Ed.N) H1B

(ii) Int Cl (Ed.) H01M

Search Examiner
M INSLEY

Date of completion of Search
16 NOVEMBER 1995

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ON-LINE: WPI

Documents considered relevant following a search in respect of Claims :-
1-18

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1361208	(ENGELHARD) see Example 2 and Figure 2	1, 2, 3 at least
X	WO 95/16287 A	(BALLARD) see whole document	1 at least
X	US 5288562 A	(MATSUSHITA) see whole document	1 at least
X	EP 0361383 A	(NKK) see whole document	1 at least
X	US 5034288	(ASEA BROWN BOVER) see whole document	1 at least
X	US 4684582	(WESTINGHOUSE) see Claim 4 equivalent to EP 231576	1 at least
X	Japio Patent Abstract Section E, Section No. 624, Vol. 12, No. 217, page 47 & JP 63013276 (MATSUYAMA TOSHIYA) see the Abstract		1 at least

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).